MATHEMATICAL MODELLING OF SPECTRUM SHARING IN COGNITIVE RADIO COMMUNICATION SYSTEMS

ABSTRACT

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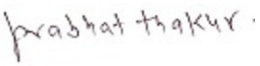
ABSTRACT

Due to exponential increase in the number of wireless connected devices (such as internet-of-things (IOTs), machine-to-machine communication (M2MC), wireless sensor networks (WSNs) etc.), these are predicted to be 75.44 billion in 2025 which is almost five times more as compared to that of the 15.41 in the year 2015. This demands huge bandwidth in the next generation communication systems however, it is a limited resource that is already allocated for certain services such as mobile telephony, military services, satellite services etc. (30 KHz - 300 GHz) which results in the spectrum scarcity. The prominent solution for spectrum scarcity is the cognitive radio (CR) technology which exploits the concept of dynamic spectrum access where the unlicensed/cognitive users (CUs) use the spectrum of licensed/ primary users (PUs) in such a way that the PUs' communication remains impervious. The CUs perceive the state of channel (active/ idle) through the spectrum sensing and accesses the channel through spectrum accessing technique (interweave/ underlay). In the interweave spectrum accessing strategy, the CU establishes communication on the idle sensed channels with full-power however, CUs establish communication on active sensed channels and interference at PU is avoided by constraining the transmitted power in the underlay technique. In the interweave spectrum accessing technique, the CU needs to stop the communication on active sensed channels which is a key challenge for seamless communication, however, has limited capacity due to constrained power transmission in the underlay technique. To enjoy the benefits and avoid the limitations of both the strategies, the combination of interweave and underlay spectrum accessing strategy is proposed and known as the hybrid spectrum accessing strategy according to which the CU accesses the idle and active sensed channels with interweave and underlay strategy, respectively. The PUs' emergence on the idle channel during CUs communication in the interweave strategy is a prominent phenomenon where the CU needs to switch the spectrum on another idle channel and this process is called as spectrum mobility. For the spectrum mobility, the emergence of PU on the channel during CU communication needs to be detected quickly and correctly, and the process to detect the emergence of PU is known as spectrum monitoring. In addition to this, the spectrum prediction is a technique to predict the future states of channels before sensing on the bases of historical information, in order to select the idle predicted channel for spectrum sensing.

In this thesis, we have initialized with the state-of-art of CR and its significance in the next generation communication systems to fulfill the huge spectrum demand. The significance of

spectrum sharing/accessing techniques in CR and encouragement as well as motivation to pursue research in this field is presented. The hybrid-cum-improved spectrum access (HISA) technique is proposed which comprises the hybrid spectrum accessing strategy with the advanced frame structures. The proposed HISA technique exploits the spectrum with reference to the spectrum accessing strategy and advanced frame structures for the improvement in throughput and data-loss of the cognitive radio network (CRN). The considered frame structures consist of spectrum sensing and data transmission phases. Further, the effect of spectrum prediction in the high traffic environment is analyzed and spectrum monitoring technique is implemented to detect the emergence of PU during the CUs data transmission for improvement in data-loss and interference-at-PU. The performance of the proposed system is analyzed through hybrid spectrum accessing strategy for various metrics of CRNs such as throughput, data-loss, and energy-loss. The spectrum prediction seems an important technique to improve the performance of spectrum sensing process by only selecting the idle predicted channels. However, if more than one channel is predicted as idle then it is difficult to select the channel for spectrum sensing therefore, we have presented a technique to select the channels for spectrum sensing on the bases of channel prediction probabilities. The spectrum sensing process without spectrum prediction suffers from the sense and stuck problem and use of spectrum prediction overcome this issue as well as improve the performance of CRN in terms of throughput. The spectrum monitoring is assumed to be a perfect phenomenon, however, in practical, the detection of emergence of PU is not guaranteed with 100% due to random nature of the channel and hardware impairments. The imperfections in spectrum monitoring cause the delay in the detection of the emergence of PU due to which the CU continues its communication even on the emergence of PU and results in the data-collision with PU. The data-collision means wastage of resources and introduction of interference-at-PU. Therefore, it is worth to analyze the effect of imperfections in spectrum monitoring on the CRNs and we have illustrated the effect on various performance metrics such as data-loss, power wastage, interference efficiency, and energy efficiency. If the issue of hardware impairments is assumed to be resolved, even though the random nature of the channel is a milestone to achieve the perfect nature of spectrum monitoring, however, one prominent way to manage the effects of imperfection is the cooperation among CUs. Therefore, we have proposed a framework where the cooperative spectrum monitoring is implemented and analyzed the effects of cooperation on the homogeneous and heterogeneous CRNs. The homogeneous CRNs are defined where all the CUs have the same probability of spectrum monitoring error however

different spectrum monitoring error in the heterogeneous CRNs. Moreover, the medium access control (MAC) protocols play a key role in the distributed cognitive radio networks (DCRNs) where more than one CUs try to access the spectrum of PU however only one establish the communication on that channel. Therefore, we have proposed a framework to enhance the spectral as well as energy efficiency by exploiting the novel frame structure in the DCRNs. The proposed framework relies on the dedicated control channel (DCC)/ common control channel (CCC) which is assumed to be always available and used to exchange the control/synchronization information of all the CUs. A self-scheduled multichannel-medium access control (SMC-MAC) protocol has been proposed for the efficient spectrum and energy utilization. Moreover, the closed-form expressions of the spectral efficiency/utilization for the proposed SMC-MAC protocols are derived. The proposed framework is analyzed for the perfect and imperfect spectrum sensing scenarios. The imperfections in spectrum sensing cause CUs transmission even in the presence of PU which results in interference at PU. Therefore, in order to analyze the effect of interference, we have presented the closed-form expression of the interference efficiency and throughput efficiency.

Moreover, due to spectral efficient nature of the recently explored techniques of non-orthogonal multiple access (NOMA), it is worth to implement this concept in the cognitive radio communication systems. Further, the emerging applications of the cognitive radio having energy limited CUs/nodes such as body area networks, WSNs, IOT etc. demands the CR frameworks which must be energy efficient. Therefore, in the future, we will work towards energy and spectral efficient cognitive radio communication frameworks. The intelligent transport system is also an emerging application of cognitive radio where the CUs need to establish communication when they are moving with a high-speed. Therefore, frequent spectrum switching and search for a channel which is available in large areas are the key concerns of the cognitive-based intelligent transport systems.